Community of prospective primary teachers facing the relative motion and PCK analysis

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Introduction

The first observations of the world done by children are related with motion of objects. Most of the perceptual aspects are activated during primary school and was subject of intensive studies concerning the psychological perception of motion (Johansson 1975, 1982, 1985; Bruce, Goldstein 1989). For this reason is important to begin to face the physic interpretation of motions already during primary school (Michelini 2005; Goldberg et al. 2010; Castells et al. 2010; Ross, Otero 2010; Brussolo, Michelini 2010).
Many learning problems on this subject, as the identification and interpretation of the role of the reference frame, the distinction between trajectory and space-time and velocity-time graph (Sokoloff et al. 1997, 2007; Beichner 1994), the vector nature of quantity as velocity and displacement (McDermott & Redish, 1999), are related to the use of a standard reductionist approach that start with the study of the particular case of the one dimensional uniform motion (Hammer 1989). A not reductionist approach (Karplus, 1977) based on the representation of displacement vectors in constant intervals of time allow instead to introduce with a more global approach the physical quantities involves into the description of motions. In particular, the contexts opened by these approach allow to study the relative motion, composition and decomposition of motion, which often are not enough stressed in the traditional one dimensional approach (Saltiel, Malgrande 1979; Viennot 1996; Castesl et al. 2010).
With these aims, a specific learning path was designed on kinematic of motion and relative motion and, at the same time, to allows primary teachers be able to introduce effectively this approach into their classrooms, a teaching formation course was designed in the prospective of PCK (Pedagogical Content Knowledge) (Schulman, 1987; Magnusson et al. 1999; Abd-El-Khalick 2006).
The aim of the present paper is to give a contribution on research about teacher formation in the PCK perspective, individuating how our training module has affected the Content Knowledge (CK) and PCK skills of teachers, in particular by responding to the research questions presented below.

Research Questions

We will analyze, with respect of our formative module on kinematic and relative motion, the following research questions:

- RQ1 How do primary prospective teachers face (as learners) the conceptual knots related to reference frames and relative motions?
- RQ2 How do prospective teachers proposed to face with their pupils the learning knots highlighted in RQ1?
- RQ3 Looking at the answers to the two previous RQ; which are the sill open aspects related to teachers CK and PCK aspects?

Context, instrument and methods

During the academic year 2009-2010, at the Faculty of Science of Education was held a specific module on kinematics and relative motions in the context of the *Physics Education* course at the University of Udine –using participated lessons. In this teaching module, the study of motions were proposed in context related frameworks beginning with the description of motions in 2 or 3 dimensions facing so, also from the first formal description of the involved entities: the vector nature of position, displacement, velocity, and acceleration; their mutual distinction and the

representation of motions into the physical space or in abstract graphs (how to read and build that representation); the definition and the role of the reference frames in the description of motions composition and decomposition of motions. The main topics addressed during the lessons are: the reference frames and their fundamental role in the description of motion; trajectory and displacement, vector and operation with them, velocity and acceleration (dealing them, as said in the introduction, directly into the two-dimensional case); displacement-time, position-time, velocity-time and acceleration-time graphs for particular important motion (i.e. circular, parabolic); Coriolis motion in 2-dimension. The formative module involved 105 prospective primary teachers enrolled in the second years of University. The average age was 22 years old (Age distribution: ~80% 21/22 years old; ~20% older).
At the end of the course a PCK-based post-test was scheduled in the week after the end of the lessons. To give answers to our research questions we analyze here what emerge from the post test, presented in the next session. The analysis of data was performed defining a priori categories, rearranged a posteriori. For each question, or group of homogeneous sub-questions, we classified the answer of each prospective teacher. The categories distribution of answers were then built.

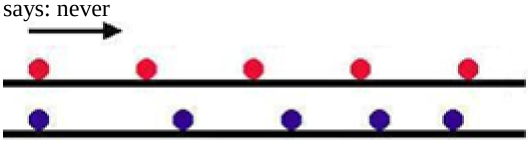
The post-test

The PCK-based consisted of 7 items: 2 on CK and 5 on PCK. A CK item concern a specific knots. Usually is constructed transforming the questions used in research about students learning. It propose a situations and the specific question exploring the extension of the concept of the prospective teachers on the specific knot considered. Item 1 reported in the Fig.1 is a typical CK item. Each PCK items was divided in two part: in the first part (the CK part), a particular situation is proposed to the prospective teachers and they have to analyze it, in the second part (the PCK part), the prospective teachers have to analyze a series of fake student questions, individuate the conceptual knot(s) at which each one of them is related and propose a way to face these knots in classroom. The item 2-3-4 reported in Fig. 1 are typical PCK questions. Here are considered just the four selected items on which we base our analysis.

Item 1. A bus trip start from Udine. The stops are Cervignano del Friuli, Trieste, Postojna, Ljubljana, Kranj, Klagenfurt, Villach. The map below shows the places touched on the journey. On the maps are represented the wind-rose and scale for distances.
1.1 Choose a reference system and it draws on the map
1.2 Represent the position vectors of the different stages: Cervignano del Friuli, Trieste, Postojna, Ljubljana, Kranj, Klagenfurt, Villach
1.3 Represent the displacement vectors for each stage
1.4 The time of travel plan is: Udine: 8.00 h; Cervignano: 8.20 h; Trieste: 9.00 h; Postojna: 10.00 h; Ljubljana: 10.30 h; Kranj: 10.50 h; Klagenfurt: 12.30 h; Villach: 13.30 h

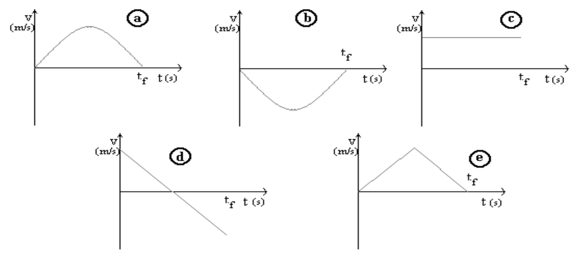
Construct the space time diagram of the motion of the bus.

Item 2. Ex 2) A teacher shows to its students the diagram below where there are represented stroboscopic image of two spheres that go right along two parallel paths. She asks to his students: when the two spheres have the same speed.
One child says: only on departure; A girl says, between the second and third position; Another child says: never



2.1 Which is/are the conceptual knot(s) highlight by the answers?
2.2 How could you face it in the classroom?

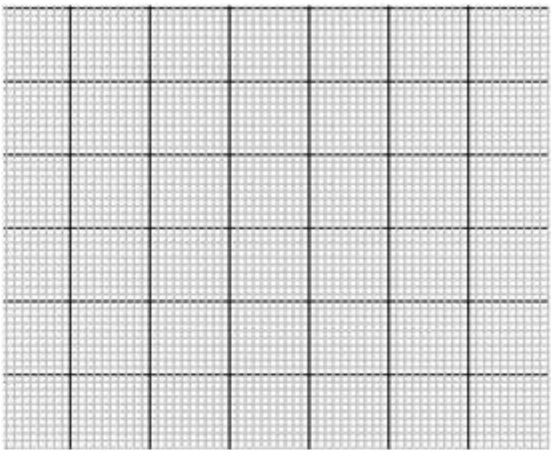
Item 3. A teacher proposed to his students the following situation: A ball is thrown vertically into the air and then take in hand when it returns to the height from which it was throw. Students must choose which of the following velocity-time graphs best describes the motion of the ball. Justify your answers and specify the trajectory followed by the ball.



Discuss each graph.

Item 4. A boat is sailing north at 40 km/h in a sea affected by a current to the east at 30 km/h constant.

4.1. Representing the boat speed and current



4.2. Represent the movement of the boat after 3 hours.
4.3. Represents in a v-t graph the boat and the current speeds
4.4. Explanation of drawing: Explain your choices for performances 4.1 and 4.2
4.5 What kind of motion are followed by boat during the three hours of navigation...
4.5.1 ... compared to the seashore? Explain your answer.
4.5.2 ... compared to the current? Explain your answer.

4.6 To some students are asked to represent the motion of the boat and explain it.
They perform the following considerations
S1: I cannot do represent motion without a compass
S2: If it isn't drawn or indicated the seashore I don't know how to do
S3: How can I represent time in a drawing of the physical space?
S4: Represent velocity at constant intervals of time is the same than represent the movement
S5: You can not represent the velocities in physical space, I must do a velocity- time graph
S6: Compared to what I have to consider the velocity?

Helping each student, explaining how (what do you say to each student?)

Figure 1. The Item 1-4 of the PKK questionannaire.

Data

Item 1. In question 1.1 the origin of the reference frame is chosen in almost all cases (92%) in coincidence of the starting point of the trip (Udine); in the remaining cases the origin point is put in the lower-left corner of the picture (3%) or in water under Udine (5%). The axes are almost always indicated (88%); there is however a significant group that drew half-axis (10%) and only one axis (2%). The axis orientation are highlighted (72%), not highlighted (18%) or are dual-oriented as the wind-rose (10%) – see Graph 1. The majority (53%) includes the two labels on the axis (E-N -33%; 20%), two marginal groups did not indicate any label (25%) or indicate the complete set of cardinal points N-S-O-E (18%).

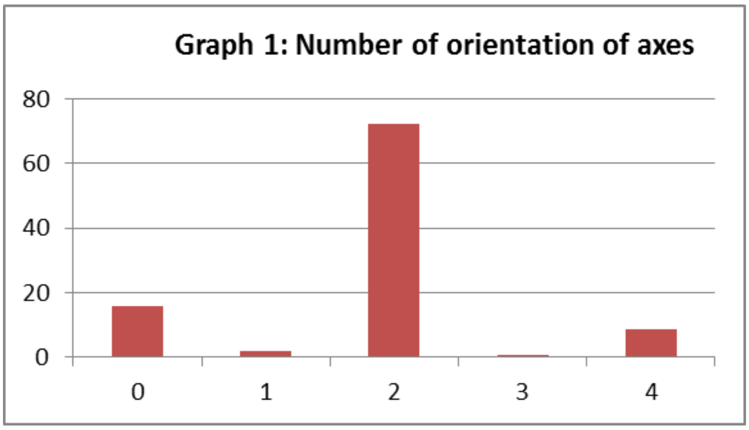


Figure 2. Number of orientation displayed

In question 1.2 and 1.3 a large majority (78%) drew the position vectors. Among these 58% also indicates the displacement vector, while 12% represent only a segment; the remaining 8% show only few elements (only the positions of the stops or the traveling as a segment or the position vectors). In question 1.4 a large group (61%) chose to represent in the graph the distance from the origin of the journey; another group (22%) interprets the delivery constructing the time-space diagram representing on the y-axes the linear distance traveled by the coach and a 9% represent the space-time graph considering equidistant one leg of the journey to the next one.

Item 2. Mostly (67%) found only one learning knots without analyze in detail each sentence, the other, or explicit a learning goals (7%), or do a CK analysis of the situation not related to the pupils answers; only 1% highlight a knots and a learning goals and the remaining part (24%) did not replay to this question. The distribution of the argumentation for the main category of answer are listed in table 1 and their distribution is shown in graph 2 in Figure. 3.

As concern the ways in which they proposed to face the knot(s) in classroom, mostly proposed an active intervention i.e. games/practical activities centered on the goals (57%); the other, or describe an activity that involves learning knots that are different from the individuate one (18%), or suggest to construct the space-time graph of the motion (3%); 22% did not replay to the question. Between the one that practical activities, 16% explicit how they are related to the specific knot, 19% describe only the activity and 22% give only a vague description of the way in which perform the proposed activity.

Table 1: Categories to Item 2	%
HIGHLIGHT A KNOT	**64**
Def. Of velocity	25
Difference: velocity – acceleration	17
Local vision of the motion	14
Diff. between velocity and trajectory	6
Do not justify	2
EXPLICIT A LEARNING GOAL	**7**
DO A CK ANALYSIS OF THE PROBLEM	**5**
Rectilinear uniform motion	4
While Ds/Dt are equals	1
KNOTS AND CK ANALYSIS	**1**
NR	**24**

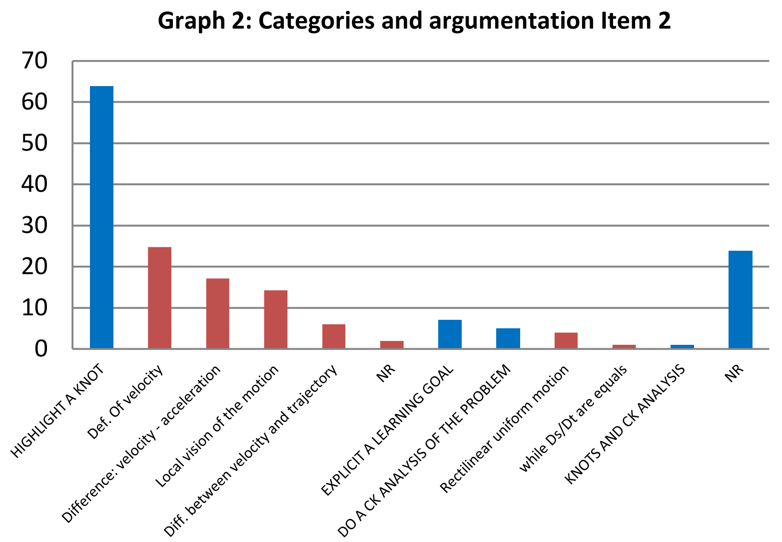


Figure 3. Answers categories and argumentations to Item 2

Item 3. The correct graph was identified as follow: 48% (a), 4% (b), 4% (c), 11% (d), 3% (e), 30% do not answer – (Graph 3 in Figure. 4)

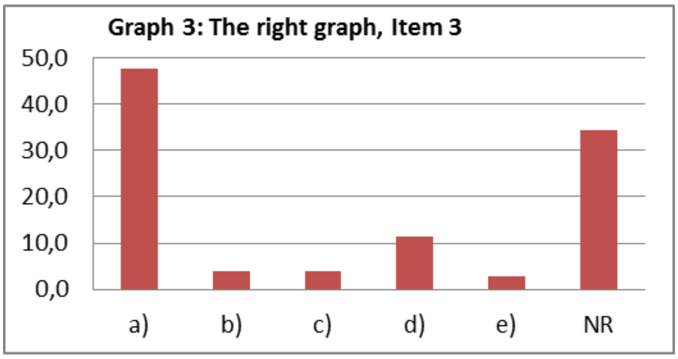


Figure 4. Graph individuate as right

More than half describe the graph (52%), without doing specific reference to the proposed physical situation describes the individual graphs; a minority but significant group (40%), analyzes the graphs doing references to the ascent and descent motion of the ball. Despite the approach that they used, mostly described the graph in terms of acceleration or change of velocity (28%+15%). In some cases someone do not distinct between trajectory and graph (16%+24%), or between space-time graph and velocity-time graphs (4%+1%).

It highlight an important prospective teachers' learning problems related for what concern the multi-representation of motions and in particular the distinction between v-t graph and trajectory.

Item 4. Concerning the representations that they did (questions 4.1-4.4): 32% define a reference system (SYS), 8% define the scale used (SC), 61% explicit velocity as vector (VV), 59% the composition of motions (COM), 51% explicit the 3 hour duration of the motion (3H), using a step by step construction of the displacement. Only 4% explicit all the five elements (SYS-SC-VV-COMP-3H); 17% explicit four elements; 24% three elements, 40% one or two elements and 15% represent anything.

As concern question 4.5.1, just under the half (49%) replied that the motion of the boat is rectilinear uniform; a no-marginal minority (13%) indicates instead that the motion is uniformly accelerated because the distance between the boat and the seashore continue to increase; 5% said that it depends by the seashore location; 2% did not specify the type of motion, buy highlight only that a composition between the two motion is needed; 30% did not replay to this question.

As concern question 4.5.2, the distribution of the right answers decrease: 35% identified the motion as rectilinear uniform, 10% as rectilinear uniformly accelerated, 48% do not answer to this question, and 7% replay “perpendicular to the current”.

Table 2: Categories to Item 3	%
DESCRIBE THE GRAPHS	**52**
Description in terms of variation of velocity	28
No distinction Trajectory, v-t graph	16
uniform accelerated motion	4
No distinction v-t, s-t	4
ANALYZE THE MOTIONS OF THE BALL	**40**
No distinction Trajectory, v-t graph	24
Description in terms of variation of velocity	15
No distinction v-t, s-t	1
NR	**8**

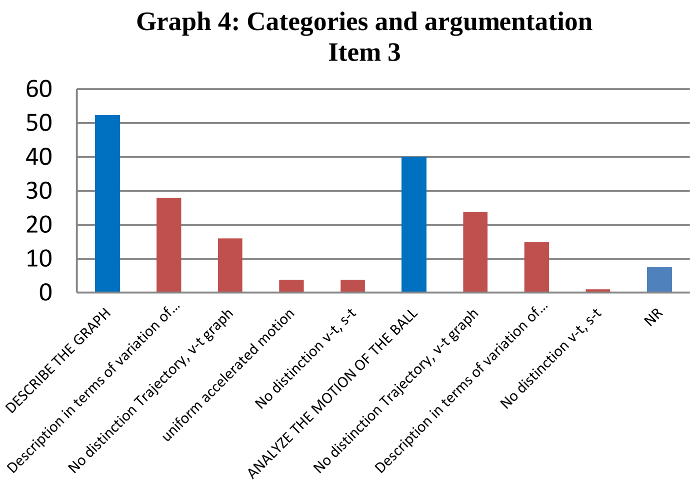


Figure 5. Categories and argumentation for Item 3

Table 3: Categories to Item 4.5.1	%
RECTILINEAR UNIFORM MOTION	**49**
Constant speed	15
/\t and /\S are equals	9
No variation of acceleration	4
It's a reference frame at rest respect to the current	3
UNIFORMLY ACCELERATED RECTILINEAR MOTION	**13**
Approach/go away from/to the seashore	7
Because of the current	3
DEPENDS BY SEASHORE LOCATION	**5**
COPOSITION OF 2 MOTION	**2**
NR	**30**

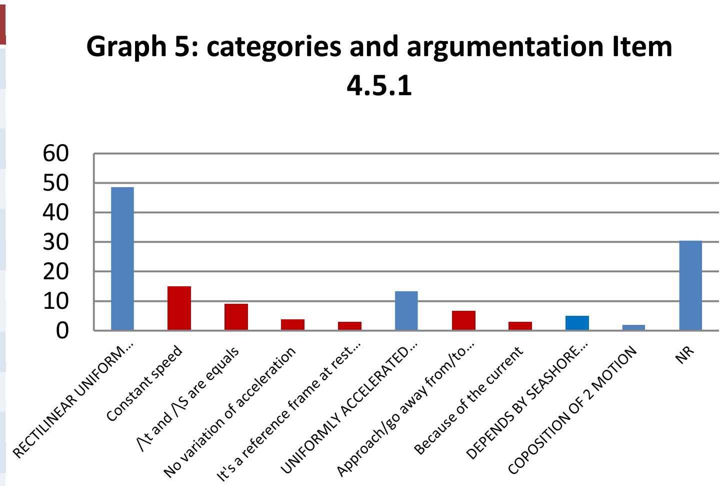


Figure 6. Categories and argumentation for Item 4.5.1

To the fake students’ answers, a large majority said to student 4.6.S1 that compass is not needed (68%), but with different argumentation: we can use an arbitrary reference frame in the representation (35%); the origin of the reference frame may be arbitrary(22%); we need only the wind rose (11%). A small minority (4%) said that it is the right answer and the remaining part (38%) do not answer to this question.

As concern 4.6.S2 more than half (52%) of the prospective teachers thinks that the position of the seashore is not important because it is not necessary that the seashore is coincident with the reference frame (27%) or because the seashore does not influence the motion of the boat (10%) or because “the motion of the boat is enough” (9%) or do not motivate or give other explanation (6%). A small group (9%) instead asserted that the seashore is the frame of reference, and 35% do not answer to this question or 4% gave other answers.

Answering to 4.6.S3 mostly of the prospective teachers proposes the construction of the space-time or the velocity-time diagram (40%); a minority (15%) suggested to represent the displacements at equal time intervals and another small group (7%) said that is impossible or not useful to introduce time in the physical space; 29% did not reply– Table 4 of Fig.7

To 4.6.S4 about one third (30%) agree with the sentences; a small group (11%) think that the sentence is wrong; A big group (41%) do not answer to this question. The argumentation to this answers are reported in Table 5 of Fig 8.

To 4.6.S4 A group disagree with the student (24%) indicating that it may be done because we considered constant Δt (16%) or introducing the velocity vector (4%), or the tangent vector to the trajectory (2%). Another group however agreed with the student (12%) arguing that we need to do a specific chart to represent it (11%). Did not reply the 52% of the prospective primary teachers.

Table 4: Categories to Item 4.5.S3	**%**
S-T OR V-T DIAGRAM	**40**
REPRESENT EQUAL /\S AT EQUAL /\T	**15**
IMPOSSIBLE/NOT USEFUL IN PHYSICAL SPACE	**7**
NOT NECESSARY BECAUSE THE MOTION IS UNIFORM	**2**
BY THE HORIZONTAL AXES OF THE REFERENC FRAME	**2**
OTHER ANSWERS	**6**
NR	**29**

Figure 7. Categories to Item 4.6.S3

Table 5 - Categories to Item 4.6.S4	**%**
YES	**30**
Because /\ T is constant	10
Because /\ T is unitary	6
V constant is related to /\s constant	6
Because v= /\s//\t	1
No argumentation	8
NO	**10**
/\s constant implies v constant, not vice versa	9
No argumentation	1
GENERAL REMARKS	**14**
OTHER ANSWER	**5**
NR	**41**

Table 6: Categories to 4.6.S5	
DISAGREE	**24**
I can because I considered constant /\t	10
as /\s//\t	5
With velocity vector	4
I can see only trajectories/displacements	4
No argumentation	2
AGREE	**12**
There is an ad hoc graph	10
I can represent only displacements	2
GENERAL REMAKS	**3**
OTHER ANSWERS	**9**
NR	**52**

Figure 8. Categories to Item 4.6.S4 and 4.6.S5

Data Analysis

Item 1. In question 1, data show that more than half of the prospective teachers build and represent a frame of reference from a map, while the others highlight some difficulties related to the identification of the axes, the choice of the orientations of these axes and the indication of the labels on the axes. The use of the cardinal points as labels is present in slightly more than half of the cases. At least, a definitely majority, even if they had construct a well defined reference frame, they has a local view of the situation as concern the selection of the origin of the reference frame. Marginal is the fraction of those who build graphs restricted to one quadrant.

Item 2. More than half of the prospective teachers highlight the presence of one knot looking at the three students' sentences as a whole without analyze in detail each one of them. A small amount swapped the learning goals for the learning knot and another group analyze the problematic situation without considered the students' sentences highlighting a tendencies in some prospective teachers to face the Item as a CK one instead of a PCK one. As concern the PCK part, we found that, even if the proposal is not really focused, the majority of the prospective teacher proposes to face the knots using active learning strategies proposing practical activities that engage the student on the analysis of the knot.

Item 3. The question is addressed by almost all of the prospective teachers, but its PCK analysis is rather transformed by them into a CK question. This tendencies, particularly high for this Item, may be due to the fact that this Item seems to be a challenge for the prospective teacher also from the CK

point of view. The problem of the right interpretation of multiple representations is a still open problem for approximately half of the prospective teachers select the velocity time graph that had the shape of a parabolic motion, and also only one tenth of them individuate the right graph (d).
As concern *Item 4*, the percentage of prospective teacher that do not answer highlighting, with a fragmentary clarity on CK, a difficult to act on focused learning knots. In particular, from the 4.5.X questions emerges (as in Item 3) difficulties related to the multi-representation the physical quantities into the physical space and the tendencies to connect the reference frame origin to something "real" as for instance the seashore. As concern the PCK part of Item 4, probably, due also to the difficulty founded into the CK part, prospective teachers only judge and comment on the CK point of view the students sentences without proposing strategy of learning intervention applicable in classroom.

Conclusions

For what concern how primary prospective teachers face the conceptual knots related to reference frames and relative motions (RQ1), from the CK part of the questionnaire we can argue that: A) the prospective teacher are able to construct effectively a well defined reference frame even there is a remaining tendencies to use a local approach into the definition of the reference frame origin; B) the multi-representation of the motion is still a problem in particular for what concern the distinction between trajectory and space (or velocity) – time graph; C) In many cases, they can apply in an effective way the step by step construction of the motion by mean of displacement vectors.
Looking at the PCK aspects (RQ2): A) The majority of the prospective teachers, especially when they consider some aspects to be mastering the CK, individuate almost one of the main knot behind the proposed question and the corresponding assertions of children, proposing also a specific activity that is effectively focused to address in classroom the knot individuated; A) at the same time, when they consider a question concerning a not well mastered content, tend to judge the correctness of the pupils answer on the instead to look for the learning knots and analyzing their origin, tend to propose generically active learning; C) in some cases, also when they evidence CK competencies, do not link the activities proposed to address with student the specific knot considered, not going beyond the generic indication "with experiments", "with games", or proposing specific games and building activity but not focused on the knot identified.
For what concern the sill open aspects related to teachers CK and PCK aspects (RQ3) we can summarize as follow: A) the main problematic CK aspects for the prospective teachers are the construction of a system of arbitrary reference frame in a given context (referring to different systems, or not related to any specific system), the reference to manage multiple reference frames in relative motion on with respect to the other, the handle of the physical multi-representation; B) the main PCK open aspects are the difficulties in recognize different learning knots in the different sentences of students, in the construction of a set of activities (and not just one) that can be used to propose to students a same aspect form different point of view, or face on a same experiment the different knots involved. As indication on how modify our formative module from one side a great attention is needed about relative motion and emphasis on the construction and role of reference frame. For what concern the PCK aspects, it emerge the need to integrate in the education laboratory of part devoted to design co-projected single activities as well micro learning path.
The results of the research presented to indicate that the formation CK is a precondition for being able to build significant PCK. At the same time, the actual construction of PCK also requires an extensive analysis of proposed activities to be able to watch the same phenomenon from different points of view, or with a variety of alternative proposals. In addition, the skill of being able to focus on a teaching of a concept called a node requires a specific design tasks.

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